Domestic Water Purification Systems and Fluoride Concentration of Home Water Supply

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Abstract

Community water fluoridation is the most effective public health measure to prevent tooth decay. But with widespread use of water purifiers to produce clean water to consumers, questions have been raised as to whether fluoride concentration in public water supply is affected by the water purifier systems that are vastly available in today's market. The objective of this study is to determine the effect of various domestic water purifier systems on the fluoride concentration in home water supply. A total of 100 water samples collected from 25 water purifier systems were included in this study. Reverse osmosis purifier systems showed significant reduction in fluoride concentration at point of use *(P=.027).* Activated carbon combination water purifier systems showed varying levels of fluoride concentrations at point of use. There was a significant increase in fluoride for the carbon mechanical plus calcium sulphite filter *(P=.01)* and for the carbon sediment plus nano filter *(P=.02)* but reduced fluoride concentration for the carbon ceramic and carbon fiber water purifier systems. This study showed that carbon-based water purifier systems may increase or reduce fluoride concentration in water but prolonged use of water purifiers using reverse osmosis technology can have long term implications on dental health.

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Introduction

Fluoride (F-) is a natural occurring mineral found in earth and present in food and water in varying concentrations[1]. The use of fluoride in improving oral health is well known as it has several caries-protective mechanisms of action such as affecting the metabolic activity of cariogenic bacteria[2]. Fluoride has also been shown to inhibit the demineralization process and enhance the remineralization of demineralized enamel[2,3]. Consumption of fluoride supplements either through systemic or topical use has also been suggested as part of an Early Childhood Caries preventive strategy[4]. Fluoridation of public water supply in controlled concentration is one of the safest and effective methods in prevention and remineralisation of dental caries[5].

Studies of children who live in territory-associated fluoride deficiency in the water have also shown that in those specific conditions caries intensity values were more statistically associated with parameters of calcium content and related mineralization coefficient[6]. It is also more cost effective to fluoridate the water supply than to treat carious teeth. The American Dental Association Executive Summary 2018 stated that compared to the cost of other prevention programs, water fluoridation is the most cost effective means of preventing tooth decay for both children and adults in the United States as the cost of a lifetime of water fluoridation for one person is less than the cost of one filling[5].

The water fluoridation programme in Malaysia was approved by the government in 1972 as a public health measure to support its caries-protective effects with due considerations given to its safety, efficiency and cost effectiveness[7]. The National Guidelines for Safe Drinking Water has cited a range of 0.4 – 0.6 ppm fluoride as the implementation range for water fluoridation in Malaysia[7]. Since its inception, dental caries status has improved especially among children. The National Oral Health Survey of 12 year-old schoolchildren in 2017 showed reduced prevalence of dental

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caries from 60.9% in 1997 to 33.3% in 2017 with reduced DMFT of 1.9 to 0.78 respectively[8].

Domestic water purification systems

Water purifier systems (WPS) are used in many households basically to remove pollutants from the tap water with the help of physical barriers, chemical processes or biological processes. The growing awareness of people towards risk of drinking contaminated water and concerns about the quality of tap water in households has led to increased usage of water purifiers in most households[9,10,11]. According to B.B.Law (2005), the popular types of WPS used in the Malaysian market are activated carbon filter, membrane filter, reverse osmosis, distillation, ultraviolet light unit and the combination unit[12]. Membrane filters such as ceramic and nano filters are used to filter larger and undesirable molecules such as virus, bacteria, salt and metal[12]. Carbon filtration systems uses activated charcoal as filtering medium to filter chlorine-based chemicals, pesticides and industrial solvents. Reverse osmosis filtration works where untreated water flows through fine filter membrane at pressure so that water passes through, but the contaminants remain behind[13]. Different types of water purifiers remove different pollutants and no single technique actually removes all the contaminants from the water[13]. Manufacturers of the WPS is continuously improving their products by using two or more treatment methods for the complete removal of contaminants[14]. The improved WPS available in the market nowadays not only remove contaminants, but also heavy ions, chlorine and bad odour and this has posed a question as to whether the fluoride that has been added to the water supply is also being filtered. Many studies have shown that reverse osmosis remove fluoride to a large extent[15], but carbon filters showed contradictory results. In her study. Loh KH et al suggested that carbon filters should be assessed individually[9]. Some studies have shown that carbon filters do not remove fluoride while other studies showed that different home purification devices such as ceramic and carbon-based removed fluoride from the tap water[16-19]. The objective of this study was to determine the effect of various domestic water purifier systems (WPS) commonly used in Malaysian households on the fluoride concentration in the water supply.

Materials and methods

Water samples

A total of 100 water samples were collected from twenty-five different households in the Klang Valley of Selangor, Malaysia over a period of six months. For the purpose of this study, water sample taken at the household tap before entering the water purifier is designated as water at 'point of entry' (POE) and water that is collected after it has passed through the water purifier is designated as 'point of use' (POU). The water samples were collected in plastic bottles (Polyethylene) which have been rinsed with deionized water twice prior to collection of the water samples to eliminate any foreign residues. Two sets of water samples were taken from each water purifier, each set consists of water samples at POE and POU thus giving a total of four water samples per water purifier. All WPS in this study had undergone regular service and maintenance according to the manufacturer's instructions. The bottles were labelled POE and POU with dates and time the water samples were taken, the brand name of the WPS and numbered to prevent mixed-up. All water samples collected were taken to the laboratory within 24 hours and analysed for fluoride content within the next 12 hours to avoid any possible increase of total dissolved solids which might impact on the accuracy of the analysis[20].

A Fluoride Low Range Portable Photometer was used to measure the amount of fluoride in the water samples. The Fluoride Low Range Portable Photometer is able to measure accurately the concentration of fluoride within the 0.00 to 2.00 mg/L (equivalent to 0.00 - 2.00 ppm)[21]. The photometer uses an advanced optical system with a combination of a special tungsten lamp, a narrow band interference filter and silicon photodetector to ensure an accurate photometric reading each time[21]. The photometer uses an adaptation of the EPA method 340.1 and SPADNS reagent to measure fluoride concentrations of less than 2.00mg/L[22]. The colored reagent is added to each water sample and the fluoride in the sample will form a colorless complex. According to the manufacturer's instructions, this associated color change is then colorimetrically analyzed according to the Beer-Lambert Law[23].

Before every water sample analysis, the photometer was validated using 10 ml of

deionized water which was filled into one cuvette using laboratory pipette followed by the addition of 2 ml of Fluoride reagent, shaken gently and left to react for 2 minutes before being placed into the holder of the photometer for the meter to be zeroed and ready for measurement. The same procedure was repeated for all water samples. Fluoride concentration is displayed in mg/L. To ensure reliability and validity, the photometer will be calibrated, and performance verification carried out using the 'Cal Check™' standard provided by the manufacturer after every five measurements.

Twenty-five percent of water samples taken from randomly chosen water purifiers were reanalysed for reliability. The Cronbach's alpha was 0.766 indicating acceptable reliability of the measurements.

Data management and statistical analysis

Data was analysed using SPSS version 26 software. Three of the water purifiers were reverse osmosis and twenty water purifiers were activated carbon in combination with other methods of filter cartridges and data were grouped according to combinations based on the manufacturers' details of each water purifier's mode, type and technology. Based on these, there were the carbon + mechanical + calcium sulphite (CMCS) group, the carbon + sediment + nano (CSN) group, the carbon + fiber (CF) group, the carbon + ceramic (CC) and the carbon + others (CO) group. The other two water purifiers use mechanical technology and is named as 'other' water purifiers.

Wilcoxon Signed-Rank test was used to compare the fluoride concentrations of drinking water before passing (POE) and after passing (POU) through the various WPS. Paired t test was used to analyse the fluoride concentrations of the water samples at POE and POU levels in each carbon group while the Kruskal Wallis test was used to compare the fluoride concentrations between the various carbon combination WPS. All analysis were computed to within 95% confidence interval.

Results

Reverse Osmosis and Others water purifiers

Water samples collected from the reverse osmosis purifier systems showed a significant reduction of fluoride concentration by 67.3% on the mean difference between POE (Mean= 0.413) and POU (Mean= 0.135), (P=.027) while for the others (mechanical) showed a 5 - 6% reduction in fluoride at the POU. (Table 1)

Type of water filtration system	Mean Fl Concentration (mg/L)		% mean difference (POE-POU)	P value
	POE	POU		
Carbon	0.385	0.419	8.9% (0.034)	.003
Reverse Osmosis	0.413	0.135	67.3% (0.278)	.027
Others (mechanical)	0.465	0.440	5.9% (0.028)	>0.05

Table 1. Analysed data for general POE and POU of carbon combination, reverse osmosis and others.

Activated Carbon combination water purifiers

There were forty samples of water obtained at POE and forty samples of water were obtained at POU. Data analysis to compare the fluoride concentrations at the POE and POU levels from the twenty-carbon combination WPS showed an overall significant increase in fluoride concentration at the point of use (P=.003). The mean difference of 0.0342 mg/L showed a percentage increase of 8.88% in fluoride concentration at the POU (Table 1).

However, analysis of data for fluoride concentration at POU between the groups CMCS (n=8), CSN (n=14), CO (n=10), CF (n=4) and CC (n=4) showed no statistical difference (P=.18) in fluoride concentrations.

Further data analysis was done for water samples within each carbon combination groups and results are shown in Table 2. The CMCS WPS which consists of carbon combination with mechanical and calcium sulphite filters showed a significant mean increase of 0.08 mg/L (23.6%) in fluoride concentration (P=.011) at POU level. The CSN WPS which consists of carbon combination with sediment and nano filter also showed significant increase in fluoride concentration at the POU level with mean increase of 0.024 mg/L (5.5%) of fluoride concentration (P=.02).

Carbon groups	POE			POU		% mean difference (POE-POU) Mg/L	P Value
	Number of water samples at each end point	Mean Mg/L	SD	Mean Mg/L	SD		
1.Carbon + mechanical + calcium sulphite	8	0.365	0.09	0.4513	0.07	23.6% (0.086)	.011
2. Carbon + sediment + nano	14	0.4343	0.12	0.4586	0.11	5.5% (0.024)	.020
3. Carbon + ceramic	4	0.375	0.10	0.355	0.17	5.3% (0.02)	.47
4. Carbon + fiber	4	0.325	0.05	0.31	0.01	4.6% (0.015)	.47
5. Carbon + others	10	0.361	0.08	0.4090	0.15	13% (0.048)	.09

Table 2. Analysed data between carbon combination groups.

There was also an increase in the fluoride concentration at the POU level for the carbon combination with other filters (CO). The mean increase was 0.048 mg/L or 13% in fluoride concentration at the POU level. However, this increase is not significant (P=.09).

The WPS which consist of carbon combination with ceramic filter (CC) showed a decrease fluoride concentration of 0.02 mg/L (5.3%) in fluoride concentration while the carbon combination with fiber filter (CF) showed a decrease of 0.015 mg/L (4.6%) fluoride concentration at the POU level. However, the decrease for both water purifiers is not significant (p>.05).

Discussion

In Malaysia, the major source of drinking water is the tap water. However, over the years there has been growing concern in the quality of the tap water supply, which leads to a growing market for household water purifiers. Water purifiers can be very effective at removing a range of contaminants from water but what is removed depends on the type of purifier that is used. Not all contaminants can be removed with a single purifier or filter, but with advanced technology, and using a combination of treatment methods, manufacturers are able to produce more sophisticated WPS that claimed to not only purify your drinking water but also give added boost and energy to the drinking water from the tap.

For the purpose of this analysis, the technology principles of the brands involved were studied and from this the WPS were grouped according to the activated carbon filters with similar combination of treatment methods. Activated carbon (AC) is widely used in WPS but in recent times however there have been significant advances towards improving the WPS by using a combination of treatment methods to deliver the cleanest possible water. In this study three groups of carbon combination WPS (CMCS, CSN and CO) showed increase in fluoride concentration after water has passed through the filter at the POU but slight reduction in fluoride concentration for CF and CC carbon combination WPS. In his study Konno et al (2008) showed that activated-carbon filters had a low absorptive capacity for fluoride ions[16]. Loh et al also stated that a standard carbon filter does not remove fluoride but with combinations of other filtration systems may contribute to either removal or some addition of fluoride in water after passing through water filtration devices[9].

This study showed that some activated carbon WPS that used combinations with other filter cartridges such as mechanical, calcium sulphite, sediment and nano filters may contribute to an increase in fluoride content at the POU. The mean fluoride concentration at POU recorded was still within the permissible range of 0.4 – 0.6 ppm allowed by the National Guidelines for Safe Drinking Water[7]. In particular the CMCS WPS also has a function to dispense alkaline water to their users[24] while manufacturers of the CSN WPS in this study claimed that the water passes through a six-stage filtration process before it reaches the POU[25]. An explanation to this increase of fluoride could be that fluoride may have been collected from the sediments or there is mineral addition from any of the cartridges in the combination to the water before reaching the POU. The effectiveness of carbon filters to filter fluoride has been discussed by B.B Law[12] whereby the physical and chemical properties, contaminant, water temperature, ph. and exposure time play a role in the effectiveness of activated carbon as water filters and therefore require regular maintenance for effective removal of impurities and contaminants. Findings from the National Oral Health Survey of Adults (NOHSA) 2010 which was the first national oral health survey to collect data on the usage of household water filters showed that an estimated 42% of Malaysian households have water filters with a higher proportion of urban households (47.7%) using the water filter compared to rural households (31.1%). Out of the total estimated households, 28.6% used the

activated carbon filters while a small proportion (5.9%) used the reverse osmosis filters[26]. However, a recent technical report in 2018 and a study by Nur Shahirah et al stated that in Malaysia the most used domestic water purification system uses reverse osmosis technology due to their performance efficiency and low electric consumption[11,27]. The reduction in fluoride concentration at POU for the reverse osmosis technology in this study was similar to other studies and this reaffirmed that reverse osmosis water purifiers reduced fluoride levels in drinking water by as much as 80 - 90%[9,15,19,28].

The 2018 Annual Report of the Ministry of Health Malaysia reported an estimated 74.1 per cent of the Malaysian population received fluoridated water. Of the total Water Treatment Plants (WTPs) available in the country, 60% of them are privatized and the fluoridation of water supply is carried out by the private sectors while the government funded the fluoridation of public water supply for WTPs operated by the government[29]. A substantial amount of money has been spent to fluoridate the public water supply in efforts to improve the oral health status of the Malaysian population and to reduce any oral health inequalities among the population. However, the use of reverse osmosis as the preferred water purification system would mean a waste of government and private sector's resources as fluoride that is added to the water is not being utilized to its potential.

This study showed that the types of water purification systems used in different households may have an effect on the fluoride content of the drinking water and may have health implications in the long term. The national oral health survey of schoolchildren 2017 have shown improved oral health status of the 12-year old schoolchildren, other national oral health surveys also reported reduced prevalence of dental caries among the preschool children which showed a reduction from 87.1% in 1995 to 71.3% in 2015 while the adults national oral health survey showed decreased caries prevalence from 94.6% in 1990 to 88.9% in 2010[26,30]. The reduction in caries prevalence in these two target groups, however is still quite small and therefore there is a need for water fluoridation to continue and to reach the consumers in safe effective amounts.

Drinking fluoridated water will ensure that fluoride ions are continuously present in the saliva and the presence of these fluoride ions can interfere with the process of caries lesion development[31]. Fluoride concentration in saliva can be enhanced by applying topical fluoride such as silver diamine fluoride (SDF) and this has been shown in studies to inhibit the tooth demineralization process and provide caries preventive effect[3]. Topical fluoride application such as SDF would be very useful for high risk patients and patients with dentine hypersensitivity[3]. However, topical application of fluoride has to be done professionally in the dental clinic. Fluoridation of water supply provides an alternative to children and communities who are unable to receive professionally applied topical fluoride and this will help to reduce oral health inequalities among the population.

Households that use the reverse osmosis technology for their water purification system can deprive their family members of the benefits of fluoride and if the household have very young children, other forms of fluoride supplements may be necessary for these young children to benefit the caries prevention effect[32]. For households that use water purification systems with activated carbon or carbon combinations, the increase in fluoride at POU is still within the permissible range while for other carbon combination systems that showed a decrease at the POU, the decrease of between 4% – 5% may not affect the benefits that water fluoridation could offer. However, further studies need to be carried out to verify and investigate the increase in fluoride concentration in these water purification systems.

Conclusions

The use of water filter that removes fluoride completely contradicts the indications for government implementing water fluoridation in public water supply for primary prevention of caries. With available scientific evidence, efforts should be made to create awareness of reduction of optimal fluoride levels in drinking water by reverse osmosis to the consumers. This study also showed that water filtration devices that used carbon filters in combinations with other filtration systems preserves water fluoridation and additional fluoride supplementations should not be necessary unless there is low initial fluoride in point of entry leading to low fluoride in the system.

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Declaration of Interest

All authors have made substantive contribution to this study and/or manuscript, and all have reviewed the final paper prior to its submission.

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